Estimations of Ammonia Emissions from Layer Facilities
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April 7, 2017

In October of 2016, I was contacted by Howard Shanker to estimate the ammonia emissions from facilities owned by the Hickman Egg Ranch, Inc. at Arlington and Tonopah, Arizona.

The number of laying hens required to emit the EPCRA reporting threshold of 100 lb/day or 45,359 g/day (number to exceed emission threshold = NEET) is calculated by dividing 45,359 g/day by the number of grams emitted per day per hen. Previous research has reported average emission rates from various single or multiple farm sources over various intervals of time that range from 0.05 to 2.00g/d-hen. The NEET ranges from 22,680 hens to 907,185 hens for 0.05 to 2.00g/d-hen, respectively (Table 1).

The objective of this report is to estimate reasonable emission factors for the Arlington and Tonopah facilities and to determine the likelihood that the EPCRA reporting threshold of 100 lb/day is exceeded at either facility. As discussed in this report, based on conservative analyses, ammonia emissions are approximately 44.3 and 36.6 times the EPCRA reportable quantity of 100 lb/day.

Table 1. Flock size required to emit 100 lb/day at emission rates from 0.05 to 2.00g/d-hen.

Emission factor	**NEET**
g/d-hen	**# hens**
0.05	907,185
0.10	453,592
0.20	226,796
0.30	151,197
0.40	113,398
0.50	90,718
0.60	75,599
0.70	64,799
0.80	56,699
0.90	50,399
1.00	45,359
1.10	41,236
1.20	37,799
1.30	34,892
1.40	32,399
1.50	30,239
1.60	28,350
1.70	26,682
1.80	25,200
1.90	23,873
2.00	22,680

Past Studies of Belt House Emissions

The National Air Emissions Monitoring Study

The Defendant's Response to Plaintiff's First Set of Non-Uniform Interrogatories to Defendant Hickman's Egg Ranch, Inc. dated 11/10/16 alleges on page 8 that the EPA, due to the criticisms of the EPA Science Advisory Board, did not adopt the NAEMS. On the contrary, the April 19, 2013 report (EPA-SAB-13-005) expressly criticized the post-NAEMS efforts by the EPA's outside contractors to develop the Emission Estimating Methodologies based on the NAEMS data and not the NAEMS itself. The response to the request for clarification from Mr. Shanker was as follows: "The Science Advisory Board identified significant flaws in the methodology and modeling approaches used in the NAEMS studies, and thus recommended that the EPA not apply the NAEMS estimating methodologies to estimate emissions beyond the specific farms that were used in the study. The EPA has never adopted the NAEMS studies as its emission-estimating methodology."

This response indicates a major misunderstanding of the Air Consent Agreement and the definition, scope and role of the NAEMS and the EEM. The NAEMS collected the data under well-defined and EPA-approved quality assurance and quality control protocol. The NAEMS data was submitted to the EPA in 2010, thus concluding the NAEMS. The EEM was to be developed after the NAEMS by the EPA itself without involvement from anyone involved with the NAEMS, including the Science Advisor. The role of the SAB was to assess EPA's approach in developing the EEM's. The NAEMS is not an EEM nor is the EEM part of the NAEMS as implied by the Defendant. In addition, the EPA has not rejected the NAEMS data for use in developing the EEMs as implied in the above statement.

The criticisms of the SAB were as follows:

1. EPA's statistical approach for estimating emissions beyond the data set provided by the NAEMS is inadequate (due to "the assumptions and forms of the statistical models"). The EPA had hired a statistician as an outside contractor who apparently had very limited knowledge or experience in livestock agriculture. This statistician made several mistakes including how she treated the negative and zero values for both direct concentration measurements and calculated emission values.
2. The SAB recommended using a "process-based" modeling approach to predict emissions. This is a great idea but will require numerous Ph.D. dissertations to fully develop these recommended process-based models. The SAB conceded that the EPA might need to rely on the statistical approach that they criticized while they are developing the process-based models and provided suggestions on how to improve the statistical approach.
3. The SAB suggested expanding the data set upon which they used to develop the EEMs. Note that they did not recommend replacing the NAEMS data set but to include other studies.
4. The SAB noted that the NAEMS does not have enough metadata (feed composition and consumption, manure production and composition, etc.) to fully inform process-based models. These components of metadata were collected/analyzed to various degrees but the SAB acknowledged that the more complete metadata would have been desirable.
5. It should be noted that the Air Consent Agreement did not promise "process-based models".
6. The EPA-funded statistician's treatment of negative and zero values was conducted without consulting NAEMS research personnel or data analysts and the director of the NAEMS (A.J. Heber) was therefore unaware of it until the EPA/SAB meeting in Raleigh, NC on March 14, 2012. Heber used the public comment opportunities to explain the negative and zero values reported by

Purdue University to the EPA in 2010. The SAB then modified their criticism of these values prior to the meeting to insisting that they remain in the data set after the meeting.

7. The SAB recommended that the broiler VOC data from the NAEMS California site was too limited in amount of data (seven 24-hour periods of sampling) to be included in the development of the EEM for VOC. This decision does not pertain to this case, which is only concerned with ammonia.

The NAEMS was a comprehensive study involving four species, buildings and open sources, and several pollutants. A large portion of the SAB report addressed open sources (manure basins and lagoons) which are unrelated to this case. The only data from the NAEMS that the SAB recommended not using for EEM development was the VOC data, due to the relatively small number of sampling events. The development of EEM for ammonia from layer facilities has not yet begun and was therefore not reviewed by the SAB. However, the data collection methods and results of NAEMS layer data have already been published as articles in reputable scientific journals (Ni et al., 2017, Wang et al., 2016, Wang-Li et al., 2013ab, Li et al., 2013ab, Ni et al., 2012, Chai et al., 2012, Li et al., 2012, Lin et al., 2012ab, Ni et al., 2011, Chen et al., 2011, Chai et al., 2010, Ni and Heber, 2010, Ni et al., 2009). The NAEMS layer results were also relied upon by the State of Arizona in estimating emissions from the Hickman facilities (ADEQ, 2016).

Ohio Belt Houses and Composting Facility (2006-07)

Zhao et al. (2016a) described a test at a farm with four mechanically ventilated belt houses containing 0.83M hens and a mechanically ventilated enclosed compost facility consisting of two large hoop structures. The manure on the belts in the houses were dried under the cages naturally with no special drying mechanism (.e.g. drying tubes, tunnels, etc.). The manure moisture content was 71±4% and 59±10% during summer and winter, respectively. The compost moisture content was 28-41%. The manure in the composting facility was turned weekly and manure was sold as fertilizer after 54 days of composting.

The NH_3 emissions were measured from both the belt houses (Zhao et al., 2016b) and the manure compost facility (Zhao et al., 2016a), giving a rare glimpse at the overall emissions from a belt house laying operation. The annual average hen-specific NH_3 emission rate from the buildings was 0.09±0.07 g/d-hen (Zhao et al., 2016b), whereas the annual average hen-specific NH_3 emission rate from the compost facility was 0.72±0.13 g/d-hen. A simple summation of the two values yields an annual average hen-specific NH_3 emission rate of 0.81g/d-hen.

Indiana Belt Houses and Manure Shed (2007-09)

The National Air Emissions Monitoring Study (Heber et al., 2011) conducted measurements at a facility with two mechanically-ventilated 280,000-hen manure belt houses (converted from high-rise houses into belt houses) and a separate naturally-ventilated manure shed (Ni et al., 2010; Ni et al., 2017). The manure belts moved 1/3 the length of the houses each day with no special manure drying system at the belts under the cages. The manure leaving the houses was directed into external manure drying tunnels that dried the manure through perforated belts using house exhaust air over a period of three days. The dried manure was transported from the drying tunnels into an externally located manure shed where it was removed throughout the year for sale to fertilizer customers.

The annual average daily mean hen-specific NH_3 emission rates from the layer houses (prior to drying tunnels) and the manure shed were 0.28±0.16 and 0.009±0.001 g/d-hen, respectively, for a total of 0.29 g/d-hen (Heber et al., 2012; Ni et al., 2010). The emissions from the drying tunnel were not reported but the drying tunnel concentrations were approximately twice that of the house exhaust air, which indicates a significant amount of ammonia was released from the manure along with moisture in the drying tunnels.

Ohio Belt House (2004-05)

Using continuous methods similar to those used by Ni et al. (2010), NH_3 emission rates from a 168,000-hen belt house in Ohio were monitored for six months from August 8, 2004 to January 31, 2005 (Heber et al., 2006) during which the average ambient temperature was 10.6□C. The 1984 high-rise house had been converted to a belt house in 2004. The manure belts were moved only one seventh of the building length daily, however, the house featured a tube drying system. The average ammonia emission rate of this house was 0.29 g/d-hen.

Iowa and Pennsylvania Belt Houses (2002-03)

Liang et al. (2005) conducted a measurement survey of belt houses and concluded that the NH_3 emission rates were 0.05 and 0.09 g/d-hen for Iowa and Pennsylvania houses with daily and semi-weekly manure removals, respectively. None of the houses had any manure drying mechanisms. Emissions from manure storage or composting were not measured.

Table 2. Summary of NH_3 emission rates from manure belt facility obtained from literature. Adapted from Zhao et al. (2016). MRI = manure removal interval for belts under cages. NEET = number to exceed the emission threshold of 100 lb/d based on the average emission rate.

Type of building(s)	MRI, d	NH3 emission rate (g/d-hen)	NEET	Reference
House (IA)	1	0.05	907,185	Liang et al. (2005)
House (PA)	3.5	0.09	503,992	Liang et al. (2005)
House (OH)	7	0.29	156,411	Heber et al. (2006)
House + manure shed (IN)	3	0.28+0.01=0.29	156,411	Ni et al. (2010)
House + compost (OH)	4	0.09+0.72=0.79	57,417	Zhao et al. (2016b)

Hickman's Arlington Facility

While the Arlington Facility is one facility, two parts of the farm are identified by the Defendant as Arlington South and Arlington North.

Arlington South Facility

The Arlington South facility consists of seven 107,463-hen layer houses, three 118,997-hen layer houses and two 189,756-hen layer houses for a total capacity of 1,488,744 laying hens (Hutson and Munck, 2015). Barns 1-7 have enclosed manure pits below A-frame cages. Manure is dried by ventilation air in these pits. Manure is removed every 9-12 days from these pits to the fertilizer facility (Phalen, 2016). Barns 8-12 are conventional manure belt systems with 2-day removal cycles into manure sheds appended to the end of the laying barns where ventilation air dries the stockpiled manure. The manure sheds serve as truck loading areas (Bonanni, 2007). Other structures are seven pullet houses (Phalen, 2017), the shell egg and further processing plants, and the feed mill.

Phalen (2017) indicates that Barns 1-12 have the manure sheds at the end of the houses, whereas Hutson and Munck (2015) indicate that Barns 1-7 have manure pits under the cages.

Arlington North Facility

The Arlington North facility consists of eight 189,756-hen houses, four 104,160-hen houses and two 147,456-hen houses for a total capacity of 2,229,600 hens. Barns 13-26 have belts that remove manure from the cages every two days into "compost" rows in sheds where ventilation air-dries the stockpiled manure. Some manure is removed from each house 5-6 days per week and each house's manure shed is completely emptied every 14 days (Phalen, 2017).

Other buildings are the shell egg processing plant, the fertilizer plant, the protein plant and the shop. The fertilizer plant takes manure from the Tonopah and Arlington facilities (Hutson and Munck, 2015).

Combined North and South Facilities at Arlington

Altogether there is a total capacity of 3,718,244 hens at Arlington. There are also 2,157,917 pullets for a total 5,876,261 chickens. However, the monthly population spreadsheet (Hickman Egg Ranch, Inc., 2017) indicated that in January 2017, there were maximum monthly average populations of 4,127,267 laying hens (May, 2013) and 2,014,877 pullets (December 2014) at Arlington.

The maximum number of laying hens at Arlington North and South facilities were 1,991,928 and 1,488,742 hens, respectively, thus the maximum number of laying hens at Arlington has been 3,480,670 hens, as compared with the 3,718,344 laying hens given by the Nutrient Management Plan (Hutson and Munck, 2015). The maximum total number of pullets at Arlington was 2,336,000 (Murphy and De Blasi, 2017c), which is slightly higher than the 2,157,917 pullets given by the Nutrient Management Plan.

There is a Vulcan Systems poultry propane rotary manure dryer, rated at 15 MBtu/hr burner at the Arlington facility. No information is available on the ammonia emissions from this manure dryer.

Tonopah Facility

This facility has a total nominal capacity of 3,072,000 hens in eleven 60,000 ft^2 barns although Huston and Munck (2014) indicated there are 14 barns at Tonopah, each holding 307,200 hens and according to Phalen (2017), barns 1-14 were constructed from September 2014 to July, 2016. The monthly population spreadsheet provided by Hickmans indicated that there are 14 laying barns. In January 2017, there were 3,344,556 laying hens and 328,065 pullets at Tonopah. Belt operation in the conventional barns is on a 4-day cycle with the belts operated for 40 min every other day, travelling half the barn length each time.

Some manure is removed 5-6 days per week (Phalen, 2017) but the 10,600 ft^2 manure-drying shed with compost rows at the end each house is completely emptied every 14 days (Phalen, 2017). The manure-drying area, with a capacity of 423,600 ft^3 of manure (Huston and Munck, 2014), is essentially a three-sided manure shed with ventilation air blowing over the top of the piles (Arizona DEQ Field Inspection Report on 2/11/15, Photo 7 and Huston Env Services Facility Layout Figure 2) and out through the open end wall. The piles are not turned as they were in Zhao et al. (2016a) and the air did not dry the manure as with the perforated belts in manure drying tunnels (Ni et al., 2010).

Other buildings are the shell egg processing plant and a pullet house.

Estimation of Emissions

The facilities farms in past studies are not exact replicas of the Hickman facilities.

1. The manure belt operation is on a 2 to 4 day cycle at Hickman's as compared with 1 to 7 day cycles of facilities studied in the past. No past studies were conducted with manure belt cycles of exactly 2 days. The sites most closely representing 2 day cycles were 1 day (Liang, et al., 2005), 3 days (Ni et al., 2012), 3.5 days (Liang et al., 2005) and 4 days (Zhao et al., 2016b).
2. The mechanically ventilated manure storage sheds with unturned windrows at the ends of the houses were not measured in previous studies. Ni et al. (2012) measured emissions from a naturally ventilated manure shed but manure had been forcibly dried in manure drying tunnels for 3 days prior to entering the shed. Zhao et al. (2016b) measured from a mechanically ventilated compost facility, however, the windrows were turned regularly and the drying air was directly from the outside as compared with moist exhaust air.
3. The Hickman facilities include both the cages and short-term manure storage. The only studies that measured emissions from the manure storage, whether composted or not, were Ni et al. (2011) and Zhao et al. (2016). Manure composting inherently releases significant amounts of ammonia, which explains the high emission rates measured by Zhao et al. (2016b). Predried manure is very stable in terms of ammonia emissions, which was confirmed by Ni et al. (2010).

A reasonable estimate would be the average of the 0.79 g/d-hen reported by Zhao et al. (2016b) and the 0.29 g/d-hen reported by Ni et al., (2010), or 0.54 g/d-hen. At this hen-specific emission rate, 84,000 hens would emit 100 lb/day. Based on this value and the maximum reported populations, the laying hens at the Arlington and Toponah facilities would emit 49 and 40 times the reportable quantity of 100 lb/day plus the emissions from the pullet houses and manure storage and treatment. The laying hens at the Arlington North and South facilities would emit 23.7 and 17.7 times the reportable quantity of 100 lb/day.

The emissions are so far above the reporting threshold that fine-tuning of the estimate is unnecessary. However, the estimate is very conservative for the following reasons:

1. The pullets at Arlington facility were not considered in the estimate.
2. The average emission rates from other studies was used whereas EPCRA indicates maximum emissions during any 24-hour period.
3. The ammonia emission from the manure dryer was not included in the estimate.
4. The effect of warmer temperatures in Arizona as compared with Indiana, Ohio, Pennsylvania and Iowa were not considered.

Figure 1. Arlington north and south facilities.

Figure 2. Tonopah facility.

References

1. ADEQ. 2016. Model of Hickman's Ammonia Emissions. Arizona Department of Environmental Quality (unpublished report).
2. Chen, Y., J.Q. Ni, C.A. Diehl, A.J. Heber, W.W. Bogan, L. Chai. 2011. Large scale application of vibration sensors for fan monitoring at commercial layer hen houses. *Sensors* 10(12):11590-11604.
3. Chai, L., J.Q. Ni, C.A. Diehl, I. Kilic, A.J. Heber, Y. Chen, E.L. Cortus, B.W. Bogan, T.T. Lim, J.C. Ramirez-Dorronsoro, and L. Chen. 2012. Ventilation rates at large commercial layer houses with two-year continuous monitoring. *British Poultry Science* 53(1):19-31.

4. Chai, C.A., J.Q. Ni, Y. Chen, C.A. Diehl, A.J. Heber, and T.T. Lim. 2010. Assessment of long-term gas sampling design at two commercial manure-belt layer barns. *J. AWMA* 60:702-710.
5. Heber, A.J., T.T. Lim, J.-Q. Ni, P.C. Tao, C.A. Diehl, H. Sun, and L. Zhao. 2006. Ammonia and Particulate Matter Emissions from a Belt-Battery Layer Barn. Final Report to Ohio Fresh Eggs, Croton, OH, March 28.
6. Heber, A.J., J.Q. Ni, B.W. Bogan, E.L. Cortus, I. Kilic, R. Zhang, L. Wang-Li. 2012. Evaluation and Analysis of NAEMS Layer Data. Final Report to the United Egg Producers, June 30.
7. Heber, A.J., J.Q. Ni, E.L. Cortus, T.T. Lim, and B.W. Bogan. 2011. National study of livestock air quality in USA. International Symp. on Health Environment and Animal Welfare, Chongqing, China, Oct. 19-22 (ISHEAW-China). p. 42-66. Beijing, China: Chinese Society of Agricultural Engineering.
8. Li, Q.F., L. Wang-Li, B.W. Bogan, K. Wang, L. Chai, J.Q. Ni, and A.J. Heber. 2013. The National Air Emissions Monitoring Study's southeast layer site: Part IV. Effects of farm management. *Trans. ASABE* 56(3):1199-1209.
9. Li, Q.F., L. Wang-Li, K. Wang, L. Chai, E.L. Cortus, I. Kilic, B.W. Bogan, J.Q. Ni, and A.J. Heber. 2013b. The National Air Emissions Monitoring Study's southeast layer site: Part II. Particulate matter. *Trans. ASABE* 56(3):1173-1184.
10. Li, Q.F., L. Wang-Li, Z. Liu and A.J. Heber. 2012. Field evaluation of particulate matter measurements using tapered element oscillating microbalance in a layer house. *J. AWMA* 62(3):322-335.
11. Lin, X.J., E.L. Cortus, R. Zhang, S. Jiang, and A.J. Heber. 2012a. Ammonia, hydrogen sulfide, carbon dioxide, and particulate matter emissions from California high-rise layer houses. *Atmos. Env.* 46:81-91.
12. Lin, X.J., E.L. Cortus, R. Zhang, S. Jiang, A.J. Heber and I. Kilic. 2012b. Thermal environmental control of high-rise layer houses in California. *Trans. ASABE* 55(5):1909-1920.
13. Liang, Y., H. Xin, H. Li, E. Wheeler, J. Zajaczkowski, P. Topper, K.D. Casey, B.R. Behrends, D.J. Burnham, and F.J. Zajaczkowski. 2005. Ammonia emissions from U.S. laying hen houses in Iowa and Pennsylvania. *Trans. ASAE* 48(5):1927-1941.
14. Lin, X.J., E.L. Cortus, R. Zhang, S. Jiang, and A.J. Heber. 2012. Ammonia, hydrogen sulfide, carbon dioxide, and particulate matter emissions from California high-rise layer houses. *Atmos. Env.* 46:81-91.
15. Ni, J.Q., C.A. Diehl, L. Chai, B.W. Bogan, E.L. Cortus, T.T. Lim, and A.J. Heber. 2010. NAEMS: Emissions Data from Two Manure Belt Layer Houses in Indiana - Site IN2B. Purdue University, W. Lafayette, IN, July 2.
16. Ni, J.Q., L. Chai, L. Chen, B.W. Bogan, K. Wang, E.L. Cortus, A.J. Heber, T.T. Lim and C.A. Diehl. 2012. Characteristics of ammonia, hydrogen sulfide, carbon dioxide, and particulate matter concentrations in high-rise and manure-belt layer hen houses. *Atmos. Env.* 57:165-174.
17. Ni, J.Q., E.L. Cortus, and A.J. Heber. 2011. Improving ammonia emission modeling and inventories by data mining and intelligent interpretation of comprehensive agricultural air quality databases. *Atmosphere* 2(2):110-128.
18. Ni, J.Q. and A.J. Heber. 2010. An on-site computer system for comprehensive agricultural air quality research. *Computers and Electronics in Agriculture* 71(1):38-49.
19. Ni, J.Q., A.J. Heber, M.J. Darr, T.T. Lim, C.A. Diehl, and B.W. Bogan. 2009. Air quality monitoring and on-site computer systems for livestock and poultry environment studies. *Trans. ASABE* 52(3):937-947.
20. Ni, J.Q., S. Liu, C.A. Diehl, T.T. Lim, B.W. Bogan, L. Chen, L. Chai, K. Wang, and A.J. Heber. 2017. Emission factors and characteristics of ammonia, hydrogen sulfide, carbon dioxide, and particulate matter emissions from two high-rise layer houses. *Atm. Env.* DOI information: 10.1016/j.atmosenv.2017.01.050
21. Ni, J.Q., S. Liu, C.A. Diehl, T.T. Lim, B.W. Bogan, L. Chen, L. Chai, K. Wang, and A.J. Heber. 2017. Emission factors and characteristics of ammonia, hydrogen sulfide, carbon dioxide, and particulate matter emissions from two high-rise layer houses. *Atm. Env.* 154:260-273.

22. Wang, K., Q.F. Li, L. Wang-Li, E.L. Cortus, B.W. Bogan, I. Kilic, W.-Z. Liang, C.H. Xiao, L.L. Chai, J.Q. Ni, and A.J. Heber. 2016. National air emissions monitoring study - Southeast layer site: Part V: Hydrogen sulfide and volatile organic compounds. *Trans. ASABE* 59)2:681-693.
23. Wang-Li, L., Q.F. Li, L. Chai, E.L. Cortus, K. Wang, I. Kilic, B.W. Bogan, J.Q. Ni, and A.J. Heber. 2013. The National Air Emissions Monitoring Study's southeast layer site: Part III. Ammonia concentrations and emissions. *Trans. ASABE* 56(3):1185-1197.
24. Wang-Li, L., Q.F. Li, K. Wang, B.W. Bogan, J.Q. Ni, E.L. Cortus, and A.J. Heber. 2013. The National Air Emissions Monitoring Study's southeast layer site: Part I-site characteristics and monitoring methodology. *Trans. ASABE* 56(3):1157-1171.
25. Zhao, L.Y., R.B. Manuzon, L.S. Hadlocon, M.J. Darr, H.M. Keener, A.J. Heber, and J.Q. Ni. 2016a. Ammonia concentrations and emissions at a commercial poultry manure composting facility. *Biosys. Engg. 150:69-78.*
26. Zhao, L.Y., X. Tong, R.B. Manuzon, M.J. Darr, A.J. Heber and J.-Q. Ni. 2016b. Ammonia concentrations and emissions at manure-belt layer houses. Unpublished abstract.

Other Documents Relied Upon

Huston, K.R. and R.F. Munck. 2014. Nutrient Management Plan, Hickman's Family Farms Tonopah Plant, HES Project No. HU14105, Huston Environmental Services, Phoenix, AZ 85045, October 31.

Huston, K.R. and R.F. Munck. 2015. Nutrient Management Plan, Hickman's Family Farms Arlington Plant, HES Project No. HU14108, Huston Environmental Services, Phoenix, AZ 85045, December 9.

Murphy, B.F., and M. De Blasi. 2017c. Plaintiff's First Request to Produce documents to Defendant Hickman's Egg Ranch, Inc.'s and Defendant's Supplemental Responses Thereto. Case No. 2:16-CV-03319, March 23, 9 pages.

Bonanni, E. 2007. Inspection of Hickman Egg Ranch. Report ID Number 98730, Arizona Department of Environmental Quality, March 19.

Murphy, B.F., F. Craig, and M. De Blasi. 2017. Defendant's First Supplemental Disclosure Statement, Case No. 2:16-CV-03319-GMS (including attached letter from Hickman's Egg Ranch, Inc. to U.S. EPA dated 8/26/06), January 10, 3 pages.

Phalen, R. 2016. Response to Voluntary Information Request. Letter to J. Abbott and E. Bonanni, Arizona Department of Environmental Quality (includes numerous enclosures), October 11, 60 pp.

Phalen, R. 2017. Replacement Continuous Release Reporting Forms for Hickman's Family Farms, CR-ERNS Nos. 1173774 (Arlington North) and 1173775 (Maricopa). Submitted to Arizona Department of Environmental Quality, March 30.

Shanker, H.M. 2017. First Amended Complaint (Violations of the Emergency Planning and Community Right to Know Act), Case No. 2:16-cv-03319-GMS, The Shanker Law Firm, PLC., Tempe, AZ, January 17, 9 pages.

Shanker, H.M. 2016. Complaint (Violations of the Emergency Planning and Community Right to Know Act), The Shanker Law Firm, PLC., Tempe, AZ, September 29, 9 pages.

Hickman Egg Ranch, Inc. 2017. Chicken Population Data from January 2011 to January 2017. 2 pages.

Uncited Documents

Proposed Stipulated Protective Order. 2017. Document 20-1. Case No. 2:16-cv-03319-GMS,

Complaint (Violations of the Emergency Planning and Community Right to Know Act).

Shanker, H.M. 2017. Plaintiff's First Request to Produce Documents to Defendant Hickman's Egg Ranch, Inc., Set No. 1 (FRCP 34]. Case No. CV-16-3319-PHX-GMS, The Shanker Law Firm, PLC., Tempe, AZ, January 31, 6 pages.

Murphy, B.F., and M. De Blasi. 2017a. Plaintiff's First Set of Non-Uniform Interrogatories to Defendant Hickman's Egg Ranch, Inc. and Hickman's Egg Ranch, Inc.'s Responses Thereto. Case No. 2:16-CV-03319, January 10, 22 pp.

Murphy, B.F., and M. De Blasi. 2017b. Plaintiff's First Request to Produce documents to Defendant Hickman's Egg Ranch, Inc.'s and Defendant's Responses Thereto, Set No. 1 (FRCP 34). Case No. 2:16-CV-03319-PHX-GMS, March 7, 8 pages.

Shanker, H.M. and R.L. Strohm. 2014. Plaintiff's First Set of Non-Uniform Interrogatories to Defendant Hickman's Egg Ranch, Inc. and Responses Thereto. Case No. CV2014-091726, The Shanker Law Firm, PLC., Tempe, AZ, November 4, 20 pp.

List of all Sworn Testimony by Albert J. Heber during Last Four Years

1. July 22, 2014. Plaintiff's Expert in Bratten, et al. v. Tyson Foods, Inc. (Lafayette, IN). Superior Court of Warren County. Case No. 3439.

   ■ Plaintiff Counsel: Trevor Galligan, Galligan and Newman, 309 Main St., McMinnwille, TN 37110.

   ■ **Defense Counsel:** Clifton N. Miller, Henry McCord Bean Miller Gabriel LaBAR, PLLC, 300 N. Jackson St., Tullahoma, TN 37388.

2. November 16, 2013. Defendant's Expert in Marsh, A.F., et al. v. Sandstone North, LLC, Sandstone South, LLC, Hollis Shafer, Carl Krusa d/b/a, Carl K rusa Farms, Genesis Pork, LLC, Western Wisconsin Weaners, LLC, and Illini Pork, LLC. Seventh Judicial Circuit of Illinois, Scott County. Case No. 2010-L-3.

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3. October 22, 2013. Plaintiff's Expert in Marsh Buck et al v. Republic Services, Inc., Allied Services, LLC, d/b/a Republic Services of Bridgeton, and Bridgeton Landfill, LLC, U.S. District Court for the Eastern District of Missouri. Case No. 4:13-cv-00801-TCM.

   ■ **Plaintiff Counsel:** Jo Anna Pollock and Ted Gianaris, Simmons Browder Gianaris Angelides & Barnerd LLC, One Court Street, Alton, IL 62002.

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4. June 4, 2013. Defense Expert in Dr. Nancy E. Warner et al. v. Precision Pork, LLC, Bethany Swine Management Services, LLC, et al. June 4, 2013. State of Illinois CircuitCourt of the 15th Judicial Circuit, County of Lee. Case No. 04-Ch-12.

   ■ **Plaintiff Counsel:** Frederick E. Roth, Roth Law Firm, 47 East Chicago Avenue, Suite 360

   ■ **Defense Counsel:** Clayton L. Lindsey, Williams McCarthy, 607 West Washington St., Oregon, IL 61061

Compensation

I receive compensation and expenses for this work at the rate of $300/hr. Sworn testimony is charged at the rate of $375/hr.

Respectfully submitted,

Albert J. Heber